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PRELIMINARY RANGE ANALYSIS OF BASELINE DEFINITION Revision (0)

INTRODUCTION

The purpose of this note is to present preliminary analysis of the spacing of network elements given the baseline definition (Revision 0) of the experimental system. The baseline definition includes R.F. characteristics for the network elements which can be translated into range information. This translation requires the definition or specification of an R.F. channel model as to path loss and characteristics of noise and interferors. The preliminary analysis assumes a path loss according to Okumura, et. al. [1] and only gaussian noise. The resultant range information must, therefore, be interpreted as an upper bound on the actual range. As more detailed models of the channel are developed through the channel characterization tests, this upper bound on range can be decreased to a more realistic value. However, useful information can be obtained as to a maximum ranges and possible network configurations based on these limiting assumptions.

Baseline R.F. Characteristics

The R.F. specifications for all elements of the network in the baseline definition are as follows:

Carrier Frequency	-	1300-1400 MHz
Effective Radiated Power	-	5-15 watts
Bandwidth	-	40 MHz

Receiver Noise Figure	-	6 db max.
Noise Improvement Factor	-	20 db min.
Antenna Type	-	omni directional in the azimuth plane with vertical polarization

The noise improvement factor is a function of the modulation method and is due to code spread of greater than 100.

Basic Relations

The basic equation which relates transmitter power, frequency, bandwidth, signal to noise ratio, noise figure, etc. to spacing of the transmitter and receiver is given in equation (1).

$$10 \log P_t/Pn = A_L(F,d) + S/N + nf - G_r - \overline{nif} \quad (1)$$

where:

P_t - Effective radiated power of transmitter

P_n - Thermal noise power (KTB)

$A_L(f,d)$ - Path loss as a function of distance and frequency in db

S/N - Signal to noise ratio in db

nf - Noise figure in db

G_r - Antenna gain of receiver antenna in db relative isotropic radiator

$\overline{nif}$ - Noise improvement factor in db

If one assumes line of sight conditions, then $A_L(f,d)$ becomes the space-loss equation:

$$A_L(f,d) = 36.6 + 20 \log F + 20 \log d \quad (2)$$

where:

d - distance in miles

f - frequency in megahertz

However, since the height of the terminal is likely to be low, this relationship is not valid. Okumura et.al.[1] provides data for modification of Equation (2) for a receiver antenna height of 3m. This modification implies the following assumptions:

1. The terrain between transmitter and receiver is "quazi smooth."

2. The local environment of the receiver is an urban area.

3. Since Okumura's results are statistical, the resulting path loss equation represents the median path loss.

Quazi-smooth is defined as flat terrain with undulation variation of less than 20 meters varying slowly. An urban area is classified as an area where tall structures are present. These might be trees, as well as buildings.

Okumura gives the path loss relative to free space loss and it is found to vary from 20 to 40 db from 1 to 10 Km from free space values, respectively. Analytic modification to Equation (2) is not feasible for a wide range of frequencies, antenna heights, and range intervals and therefore, the space loss equation (2) is corrected by reading values from Okumura's curves.

Figure 1 represents the median signal to noise margin for 1317 MHz as a function of distance in kilometers using Equation (1) and Equation (2) modified. The free space curve does not include the Okumura correction. It should be noted that two different transmitter heights are given and one can expect approximately a 5 db variation between 140m and 45m height antennas. Based on these curves and the requirement for a probability of bit error of 1×10^{-5} which is roughly equivalent to a 12 db signal to noise ratio for D.C.P.S.K., then the approximate maximum distance between a terminal and repeater is 2.3 miles for 45m antenna and 3.3 miles for 140m antenna height. Figure 2 represents the median signal to noise margin for 453 MHz as a function of distance in kilometers

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with all other parameters held the same. The 12 db points for the two antenna heights of 45m and 140m are 3.4 and 9.2 miles, respectively. These distances assume no other forms of interference, such as ignition noise or other packet transmissions, and therefore, might be reduced appreciably if an additional 10 db or more margin is necessary for a given bit error rate. This can be illustrated by the fact that all the curves have an approximate 8 to 9 db per octave slope which means that 10 db of additional margin would reduce the ranges by more than 50%.

One final comment should be made concerning the fact that these curves represent the median signal to noise margin due to Okumura's statistical representation of path loss. Okumara also gives information concerning the variance of this data and indicates that approximately 12 db must be added to the path loss or subtracted from median signal to noise margin to insure a .99 probability of signal margin being greater than that value. This would also reduce the range by more than a half and leave, for example, a range 0.8 miles for a 45m height antenna at 1317 MHz.

The spacing of elements in the network will be dependent on this spacing between terminals and repeaters since repeaters will be spaced to cover a region so that a terminal will be able to communicate with at least two repeaters. If the repeater antenna heights are 45m or higher, then their path loss will be near that of free space attenuation, which implies that there will be 20 to 40 db of additional signal to noise margin over repeater to terminal transmissions.

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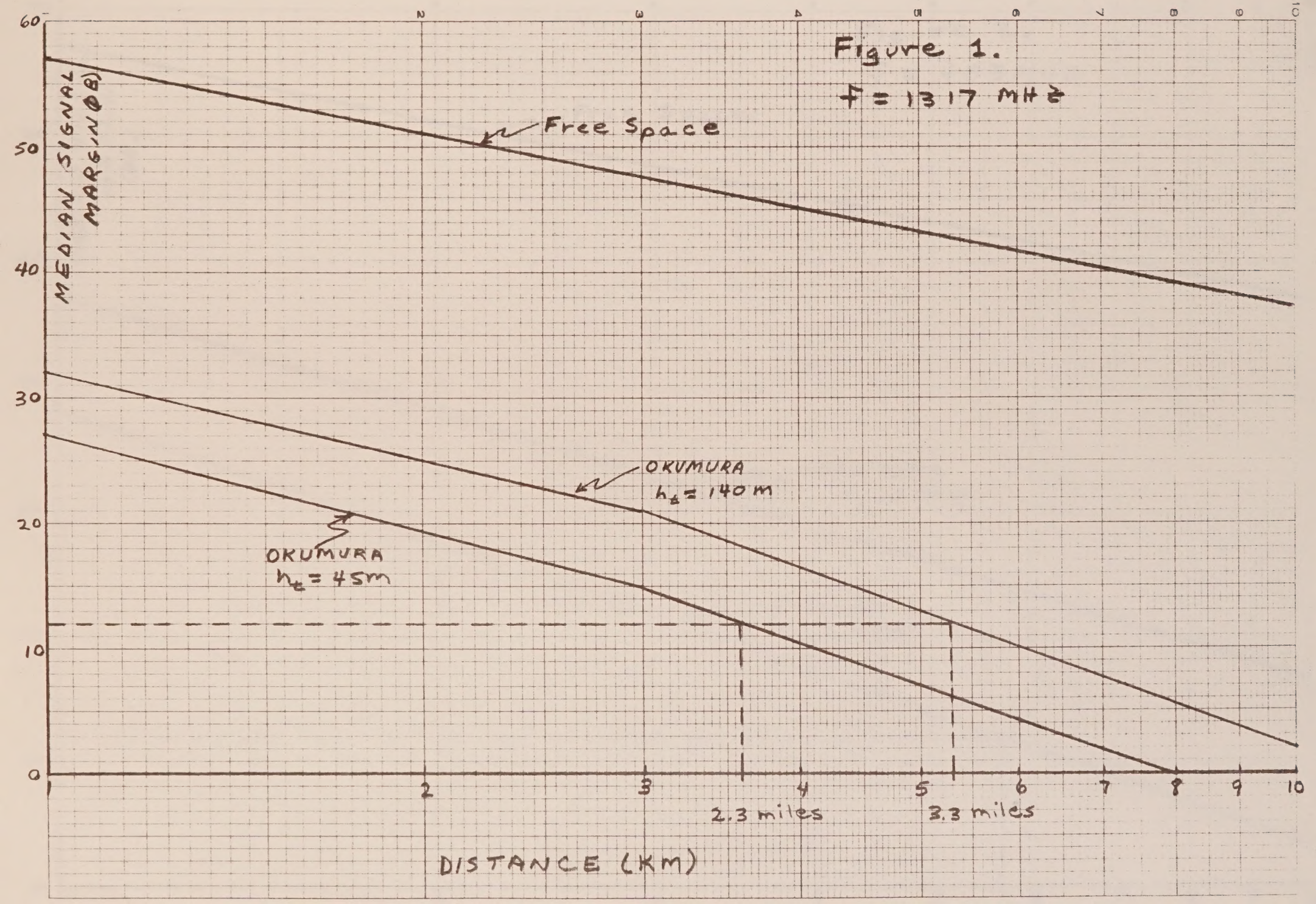

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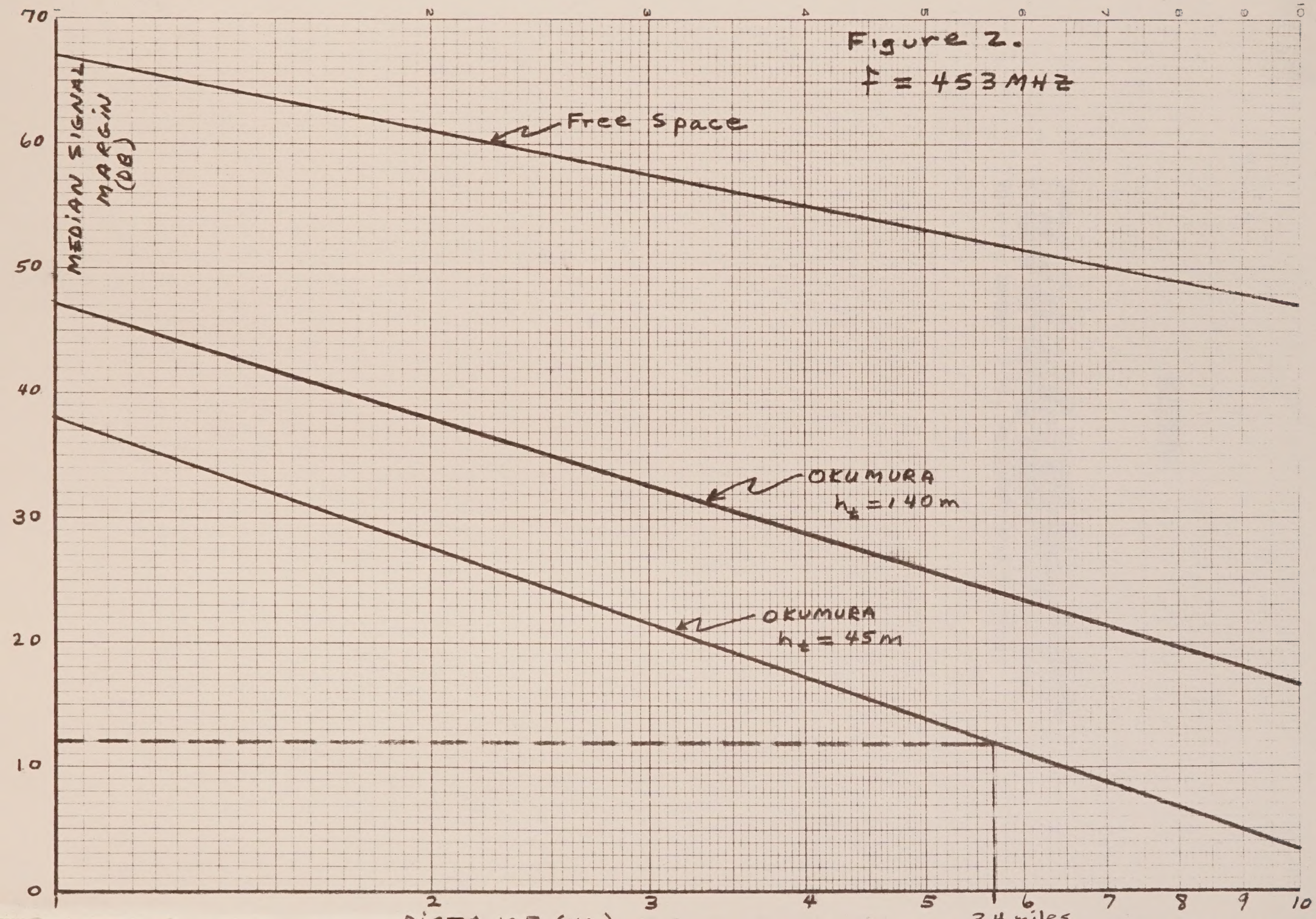

REFERENCE

1. Okumura, et. al., Field Strength And Its Variability In VHF and UHF Land-Mobile Radio Service, Review of the Electrical Communication Laboratory, Vol. 15, numbers 9-10, September-October, 1968.